VALIDATION OF ESTIMATED VALUES OF SATURATED HYDRAULIC CONDUCTIVITY AND ATTERBERG LIMITS IN SOIL SURVEY REPORTS

Cooperative Research Agreement

University of Puerto Rico – Agricultural Experiment Station

USDA- Natural Resources Conservation Service

PROJECT PARTICIPANTS

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USDA- NRCS

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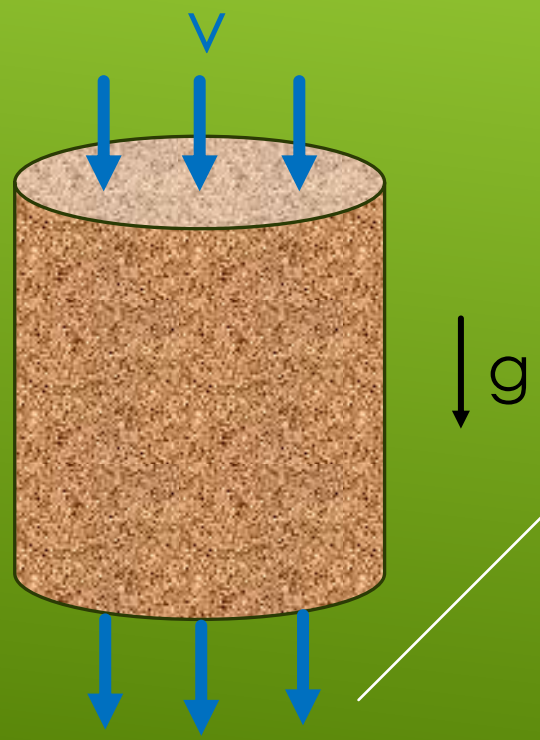
PROPERTY DEFINITIONS (K_{SAT})

Saturated hydraulic conductivity (K_{sat})

Velocity (μm/sec) at which liquid water can flow through saturated soil under a unit hydraulic gradient (driving force equal to that of gravity)



KNOWLEDGE OF K_{SAT} IS REQUIRED FOR:

- Hydrologic and erosion modeling.
- Design of Best Management Practices (BMP) for soil and water conservation.
- Design of irrigation and drainage systems.
- Septic system design.
- Land application of liquid waste materials.
- Engineering design of earth structures and foundations.

- **ESTIMATED VALUES OF K_{SAT} FOR ALL SOIL SERIES SUPPLIED IN SOIL SURVEY REPORTS**
- Values specified in ranges or classes

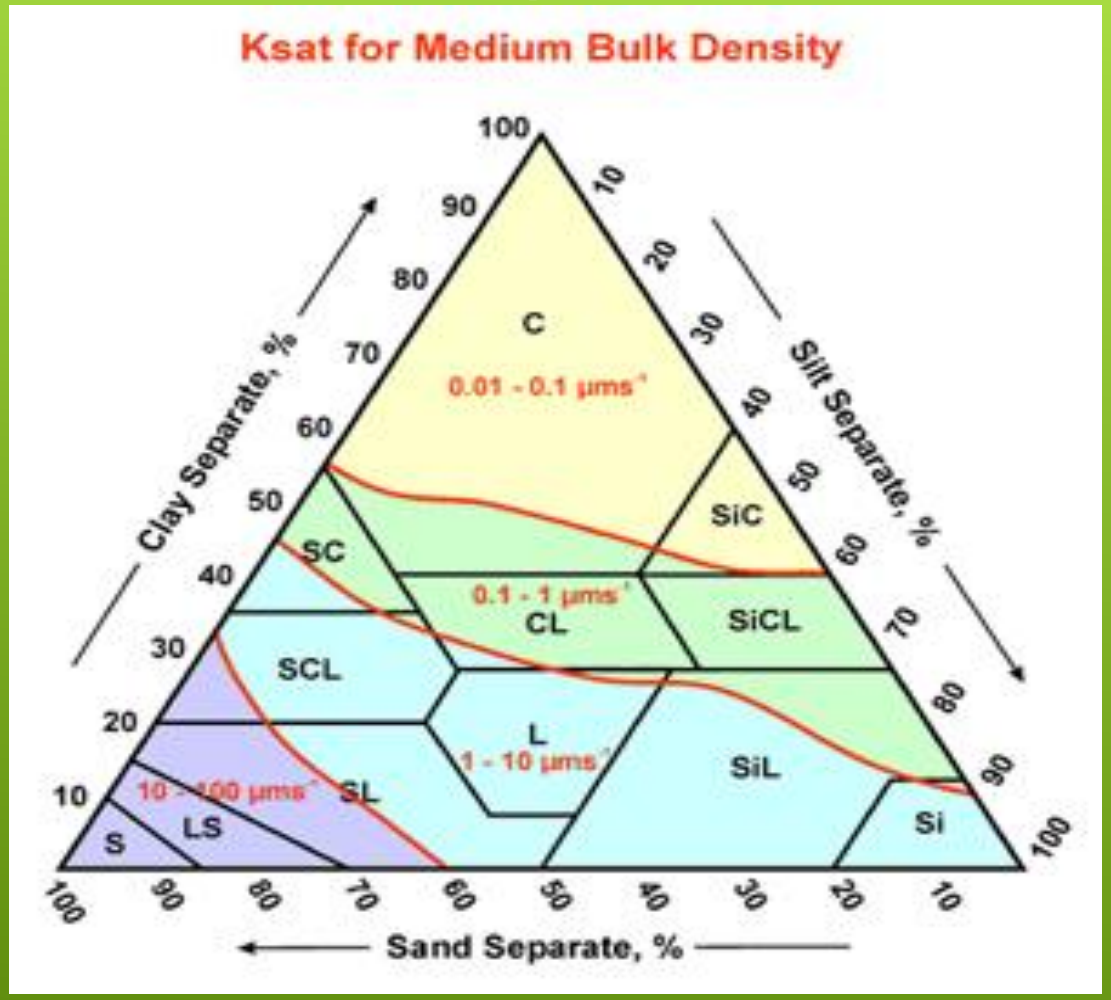
K_{sat} range (µm/sec)	Hydraulic conductivity class
< 0.01	Very low
0.01 – 0.10	Low
0.10 – 1.00	Moderately Low
1.00 – 10.00	Moderately High
10.00 – 100.00	High
> 100.00	Very High

CRITERIA FOR ESTIMATING K_{SAT} (NSSH: PART 618.88):

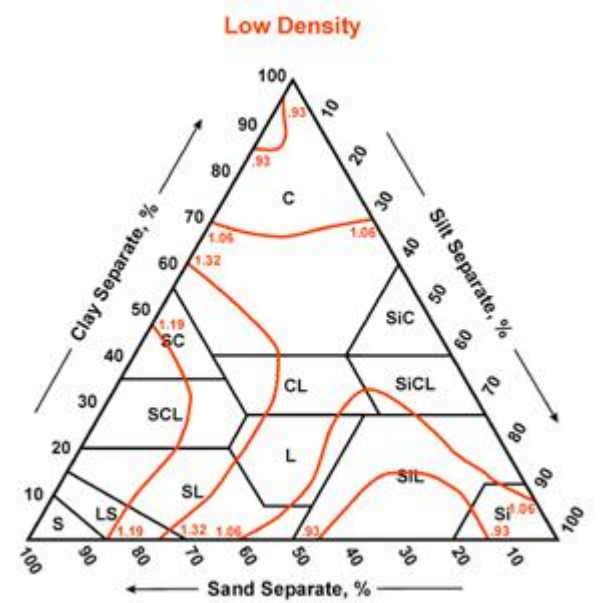
- Soil texture classification
- Bulk density classification (low, medium, high)
- Soil structural description
- Surface activity (CEC/clay)

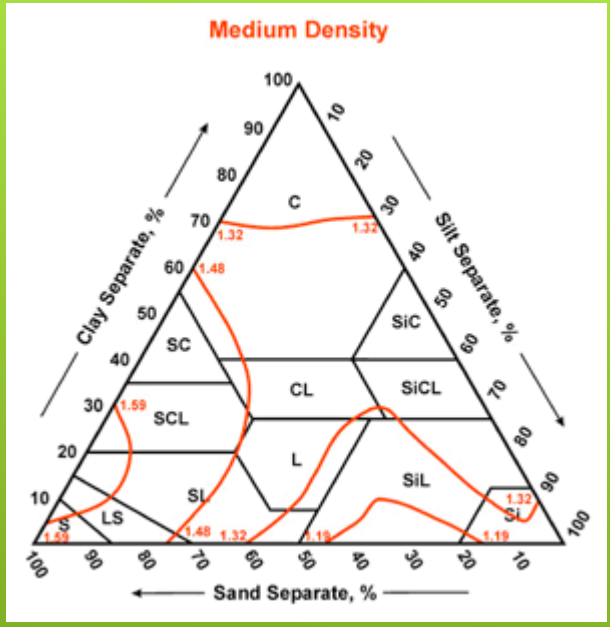
Estimation of K_{sat} based on:

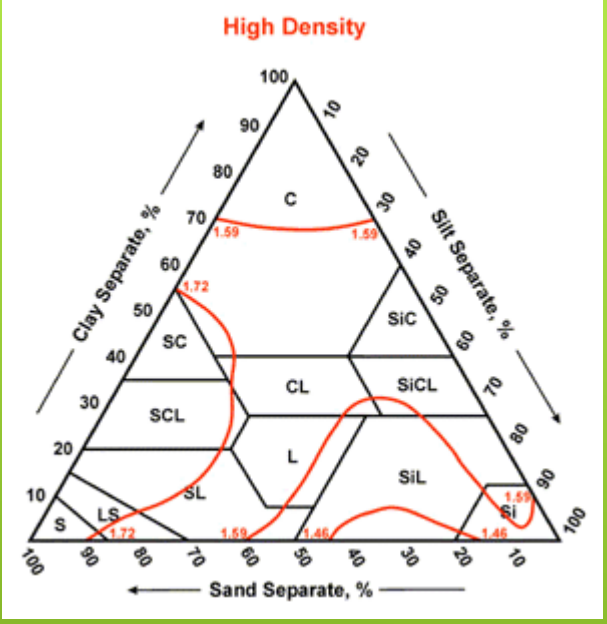
- Soil texture and bulk density

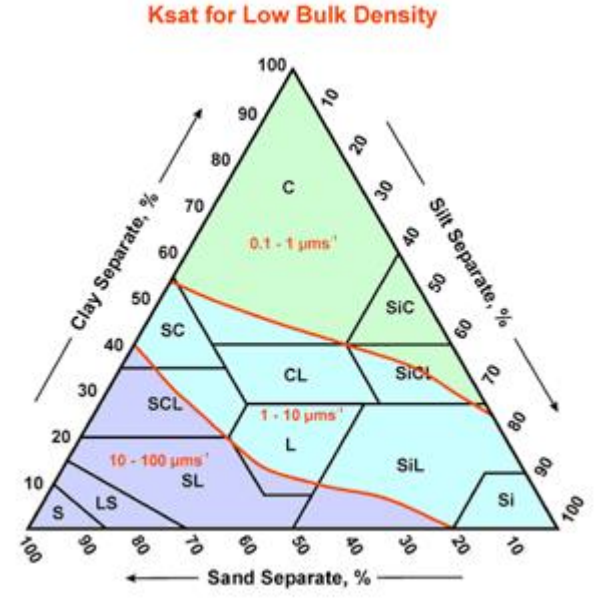


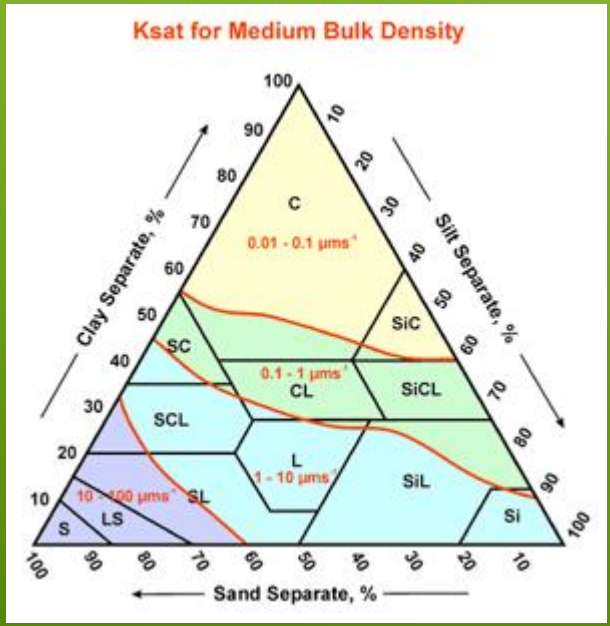
- Overriding modifiers dependent on soil structure and surface chemistry

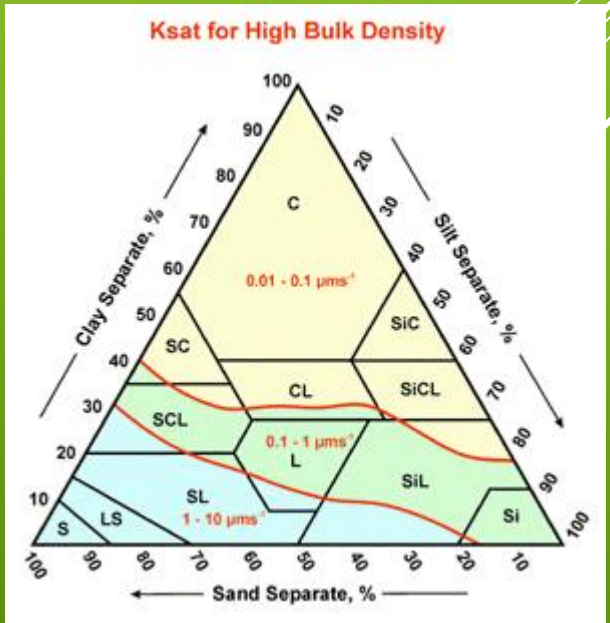

Low Density
Clay Separate, %
Silt Separate, %
Sand Separate, %
C
SiC
SC
CL
SiCL
SCL
L
SiL
SL
Si
LS
S


Medium Density
Clay Separate, %
Silt Separate, %
Sand Separate, %
C
SiC
SC
CL
SiCL
SCL
L
SiL
SL
Si
LS
S


High Density
Clay Separate, %
Silt Separate, %
Sand Separate, %
C
SiC
SC
CL
SiCL
SCL
L
SiL
SL
Si
LS
S


Ksat for Low Bulk Density
Clay Separate, %
Silt Separate, %
Sand Separate, %
0.1 - 1 µms⁻¹
1 - 10 µms⁻¹
10 - 100 µms⁻¹
C
SiC
SC
CL
SiCL
SCL
L
SiL
SL
Si
LS
S


Ksat for Medium Bulk Density
Clay Separate, %
Silt Separate, %
Sand Separate, %
0.01 - 0.1 µms⁻¹
0.1 - 1 µms⁻¹
1 - 10 µms⁻¹
10 - 100 µms⁻¹
C
SiC
SC
CL
SiCL
SCL
L
SiL
SL
Si
LS
S


Ksat for High Bulk Density
Clay Separate, %
Silt Separate, %
Sand Separate, %
0.01 - 0.1 µms⁻¹
0.1 - 1 µms⁻¹
1 - 10 µms⁻¹
C
SiC
SC
CL
SiCL
SCL
L
SiL
SL
Si
LS
S

Overriding condition	K_{sat} (µm s^{-1})
All fragmental, cindery or pumiceous	≥ 100
Many medium or coarser vertical pores that extend through the layer.	≥ 100
Medial-pumiceous, medial-skeletal, ashy-pumiceous, ashy-skeletal, hydrous-pumiceous that is very friable, friable, soft, or loose.	10 – 100
When moderately moist or wetter, structure that is moderate or strong granular, strong blocky or prismatic smaller that is very coarse and no stress surfaces or slickensides.	10 – 100
Common medium or coarser vertical pores that extend through the layer.	10 – 100
Strong very coarse blocky or prismatic and no stress surfaces or slickensides.	1 – 10
≥ 35 percent clay, soft, slightly hard, very friable or friable, no stress surfaces or slickensides and the clay is subactive after subtracting the quantity (2 x (OC x 1.7))	1 – 10
Few stress surfaces and/or slickensides.	0.1 – 1
Massive and very firm or extremely firm, or weakly cemented.	0.1 – 1
Continuously moderately cemented.	0.1 – 1
Common or many stress surfaces and/or slickensides.	0.01 – 0.1
Continuously indurated or very strongly cemented.	< 0.01

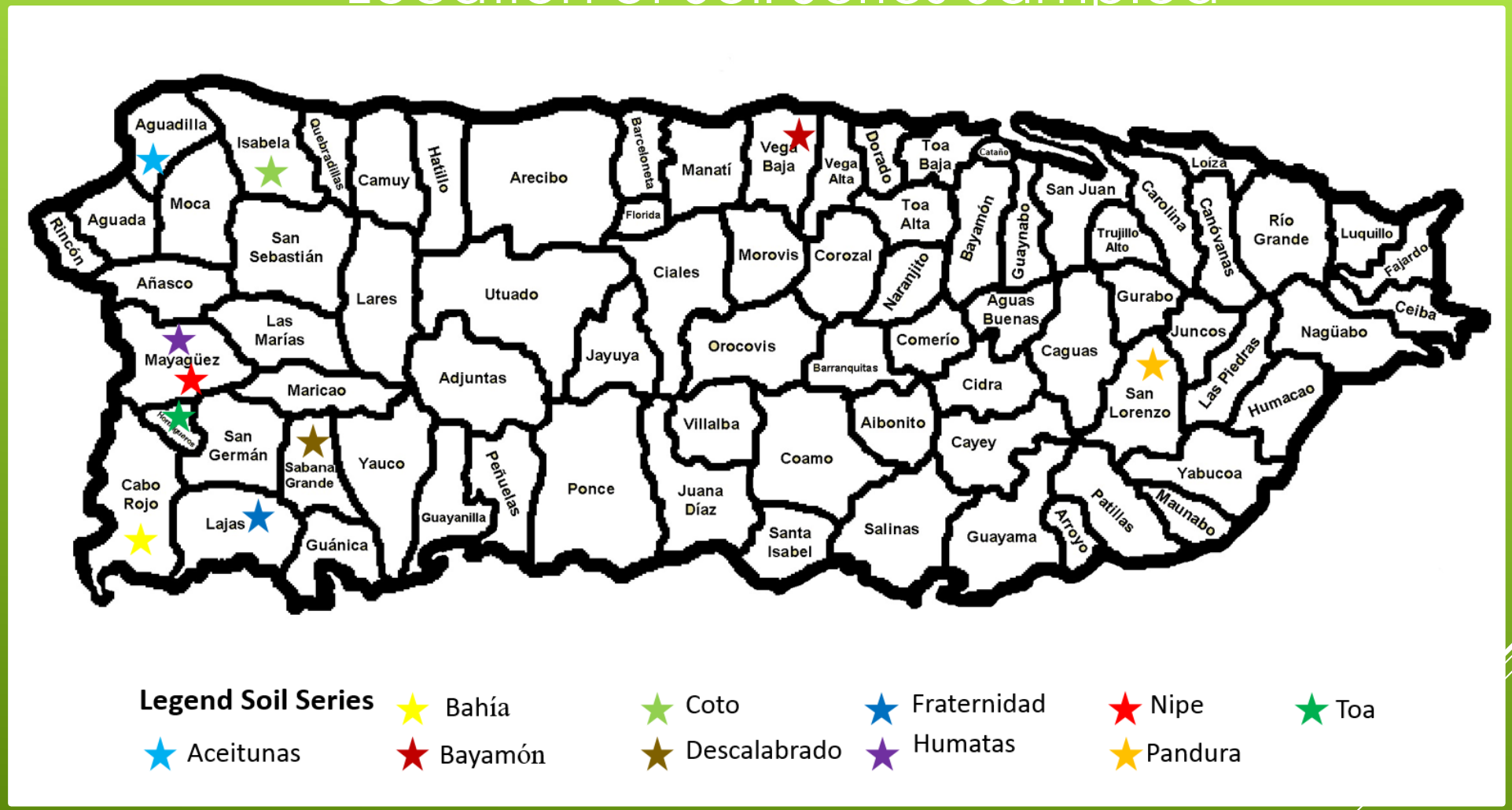
RESEARCH OBJECTIVES

1. Obtain multiple in-situ K_{sat} measurements (n=12 or 16) in major horizons of 11 benchmark soil series of Puerto Rico.

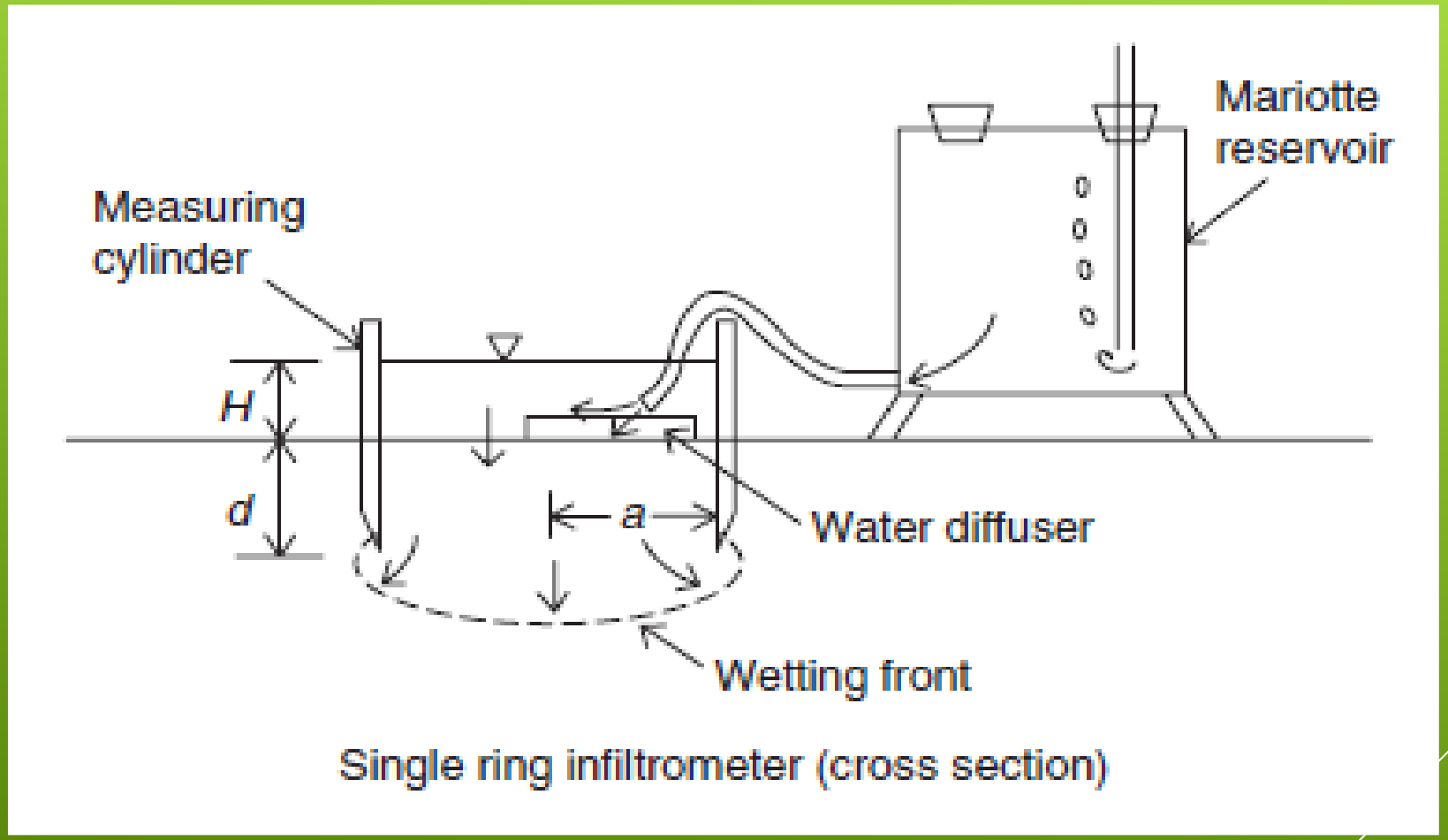
2. Determine the extent to which measured K_{sat} values occur within the estimated K_{sat} class listed in Soil Survey reports.

Soil series	Taxonomic classification
Nipe (Bo)	Very-fine, ferruginous, isohyperthermic Anionic Acrudox
Coto (Bo)	Very-fine, kaolinitic, isohyperthermic Typic Eutrustox
Bayamón (Bo)	Very-fine, kaolinitic, isohyperthermic Typic Hapludox
Aceitunas (Ap, Bt)	Fine, kaolinitic, isohyperthermic Typic Paleudults
Humatas (Ap, Bt)	Very-fine, parasesquic, isohyperthermic Typic Haplohumults
Bahía (Ap, Bt)	Mixed, isohyperthermic Psammentic Paleustalfs
Pandura (B)	Coarse-loamy, mixed, active, isohyperthermic, shallow Dystric Eutrudepts
Descalabrado (Ap)	Clayey, mixed, superactive, isohyperthermic, shallow Typic Haplustolls
Toa (Ap)	Fine, mixed, active, isohyperthermic Fluvaquentic Hapludolls

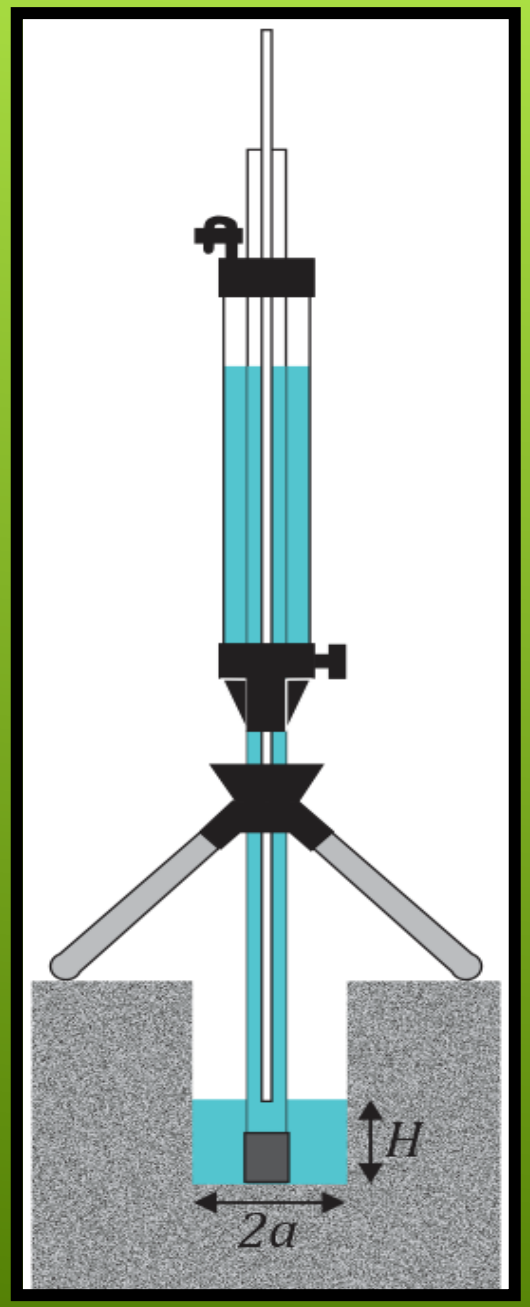
Location of Soil Series Sampled



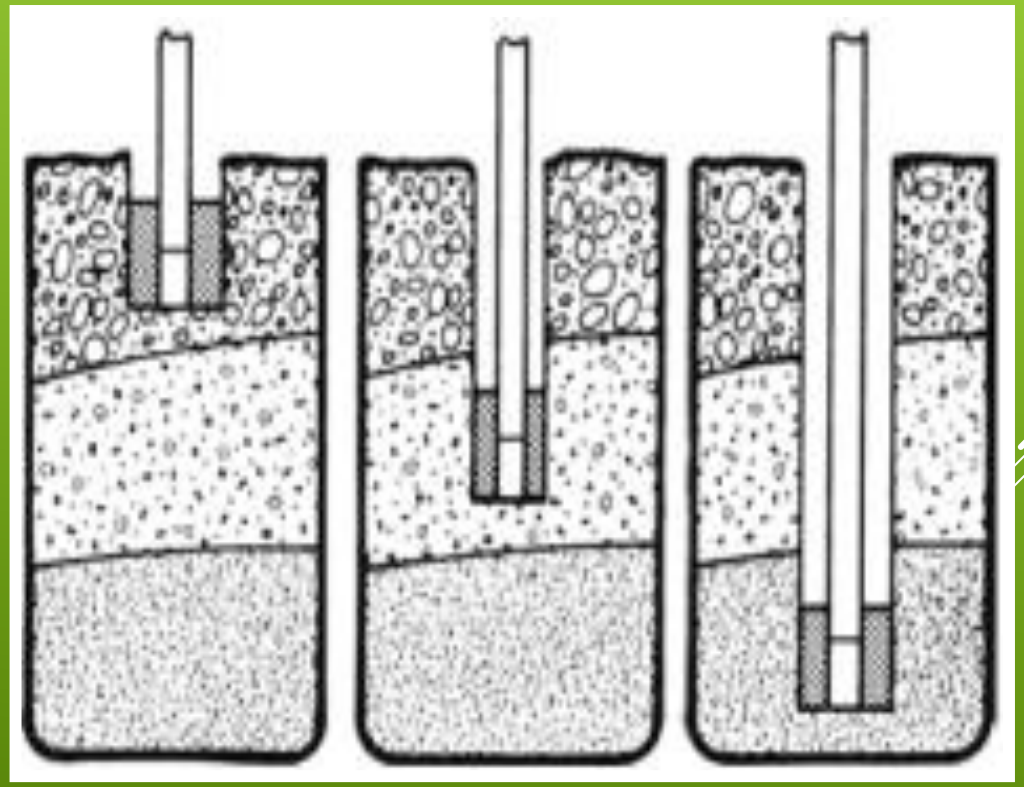
Ring infiltrometer diagram for surface measurements

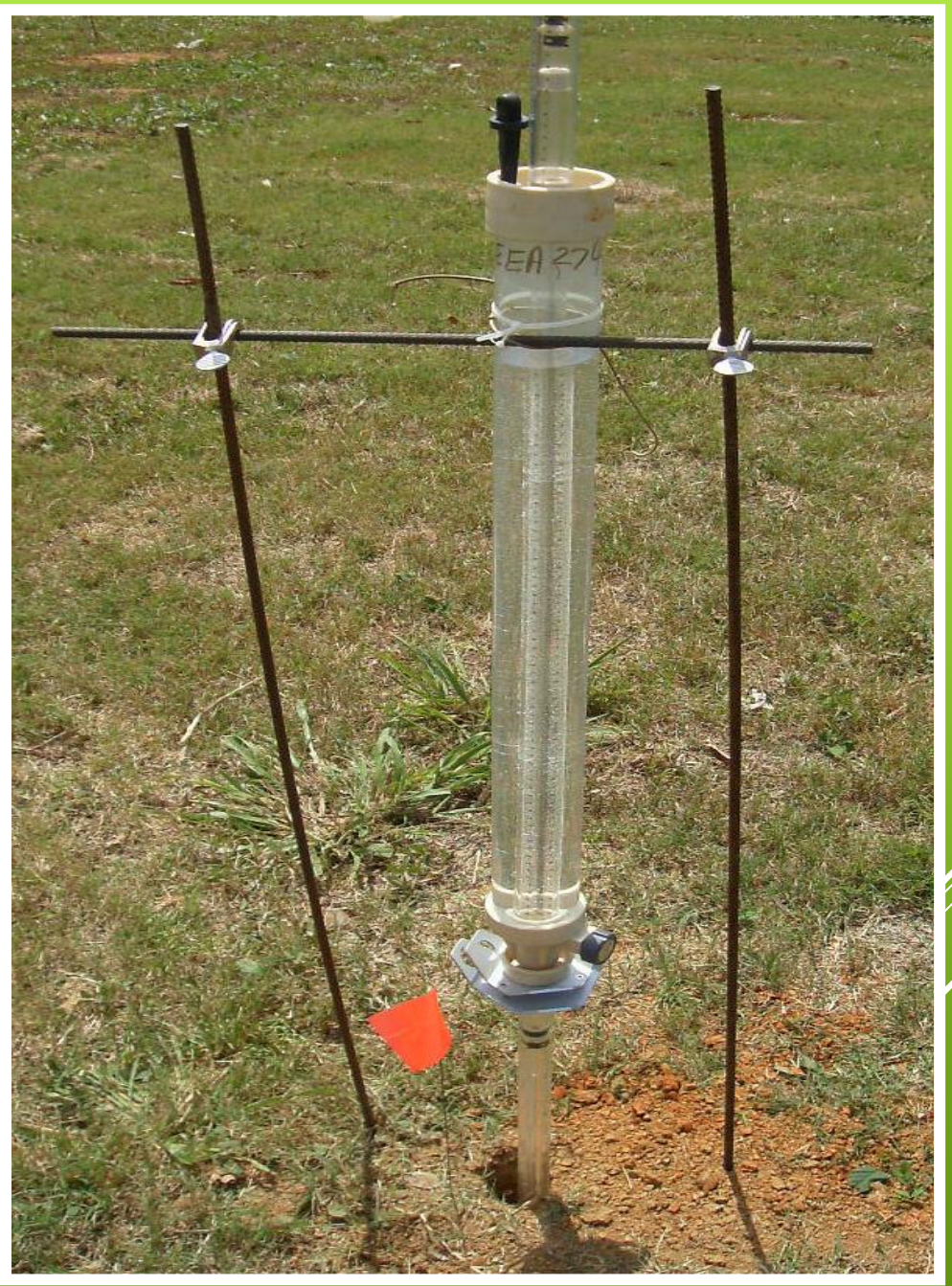


Single ring infiltrometer (cross section)

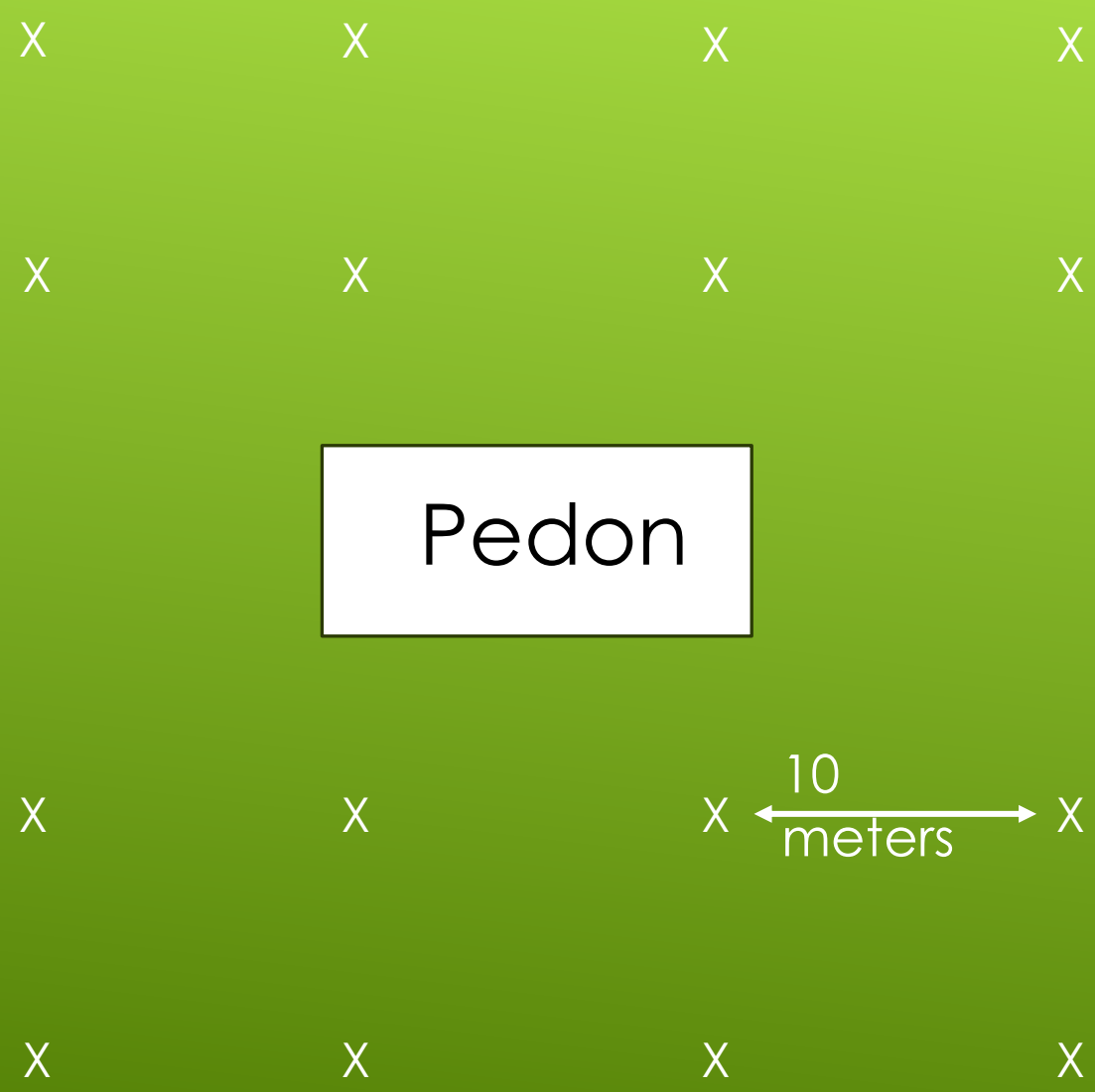


Well permeameter diagram for subsurface measurements.

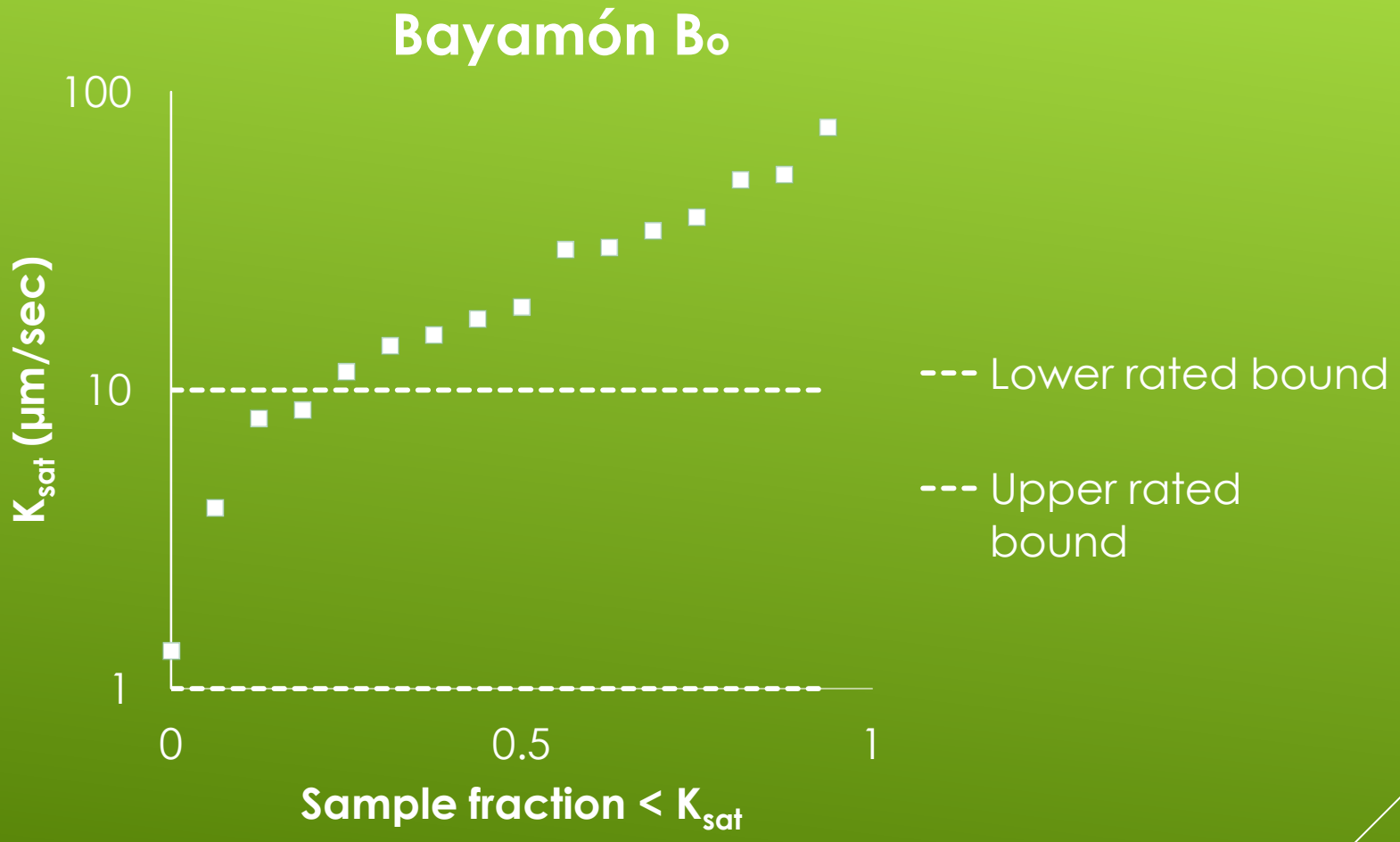


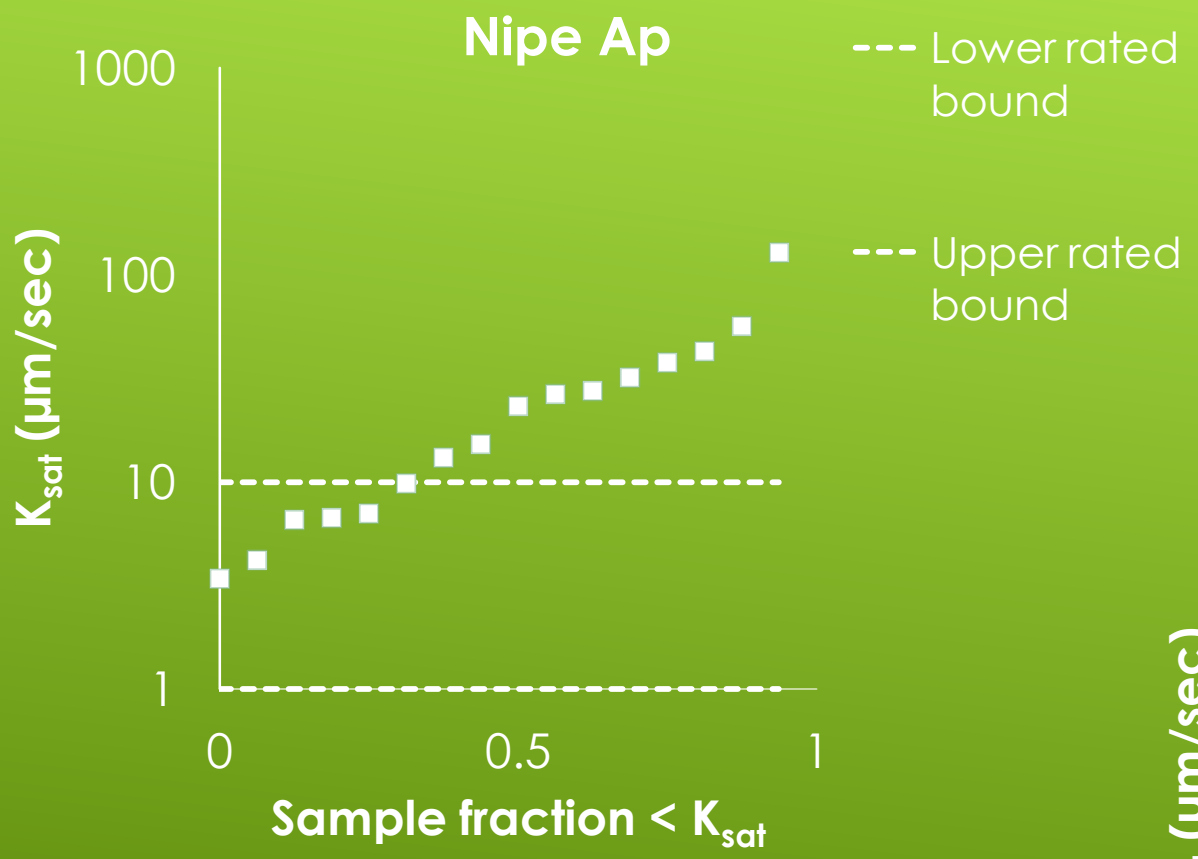


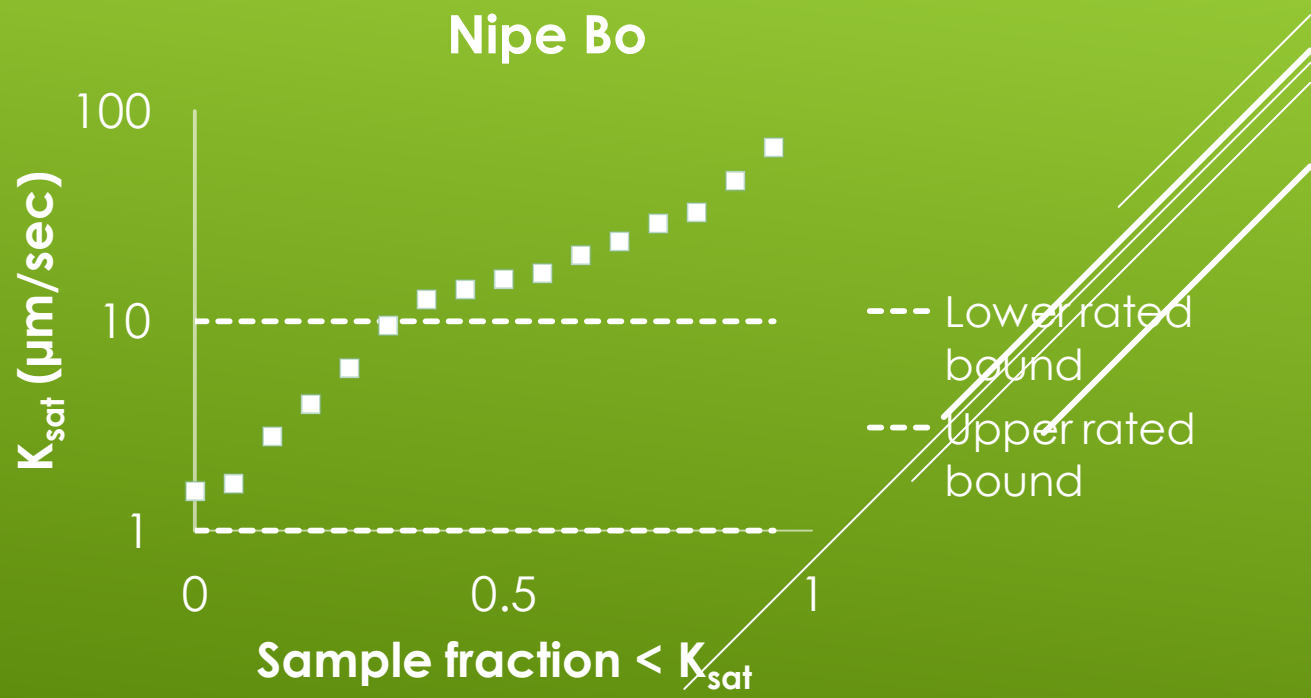
SAMPLING GRID CONFIGURATION FOR EACH SERIES

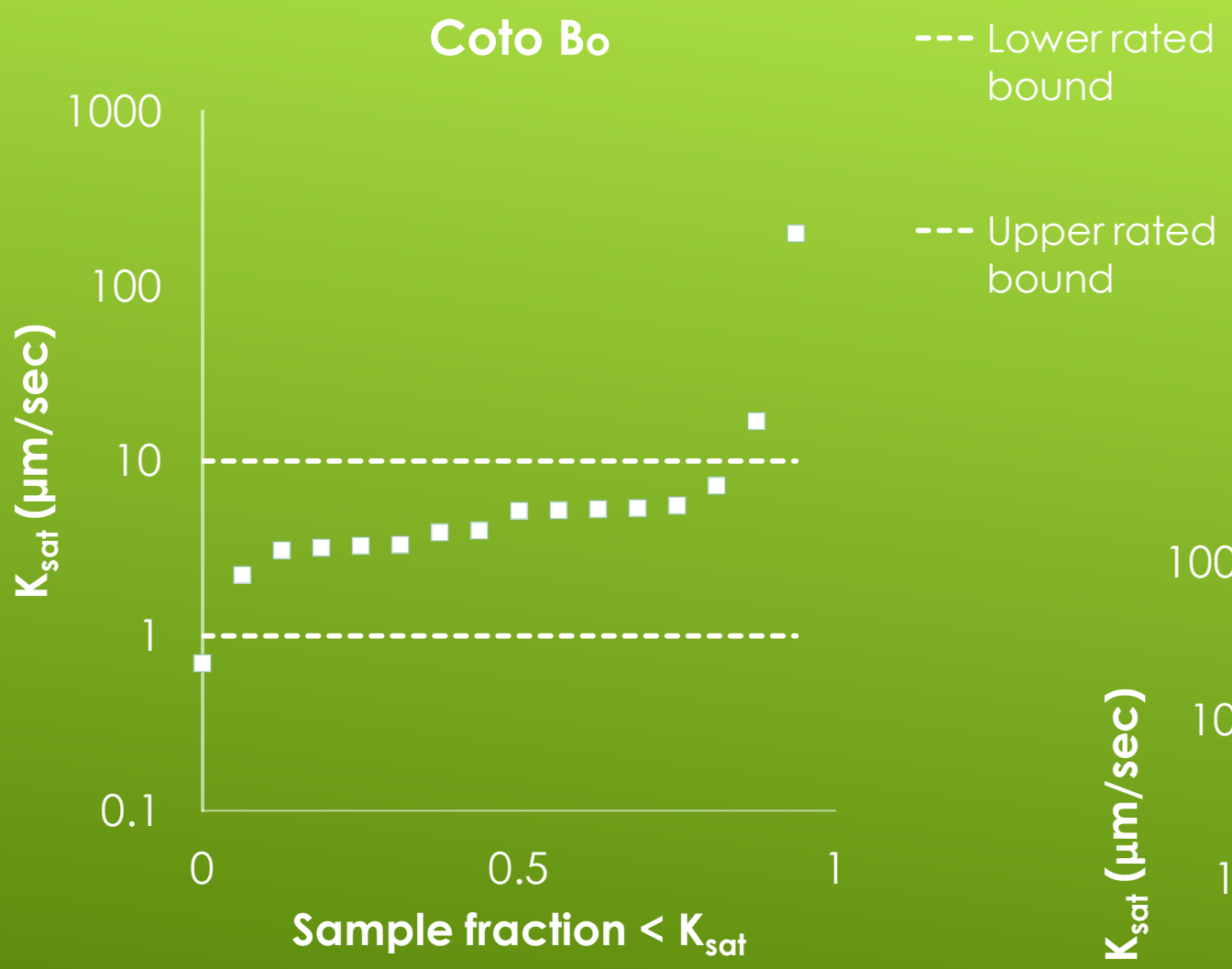


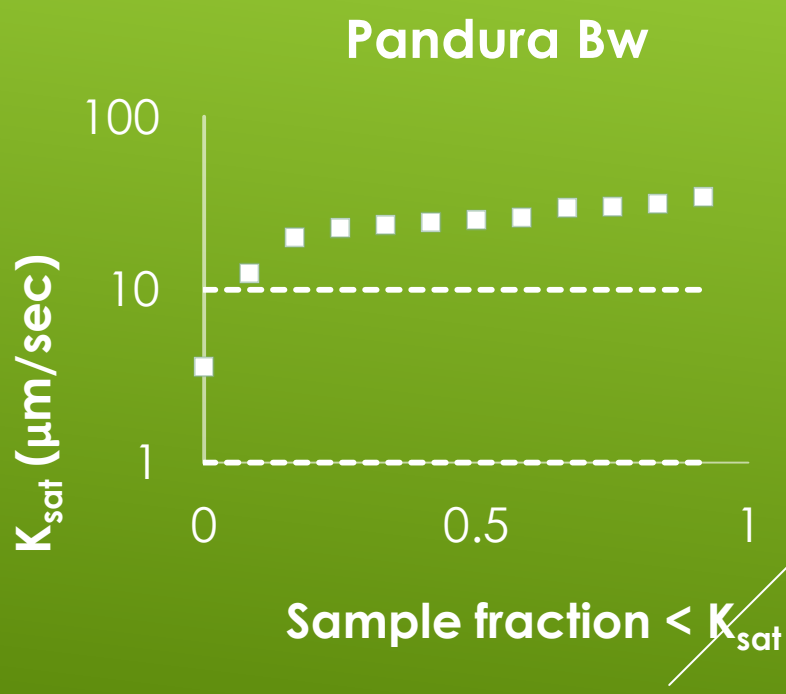
RESULTS


Bayamón Bo
100
10
1
0
0.5
1
Ksat (µm/sec)
Sample fraction < Ksat
Lower rated bound
Upper rated bound

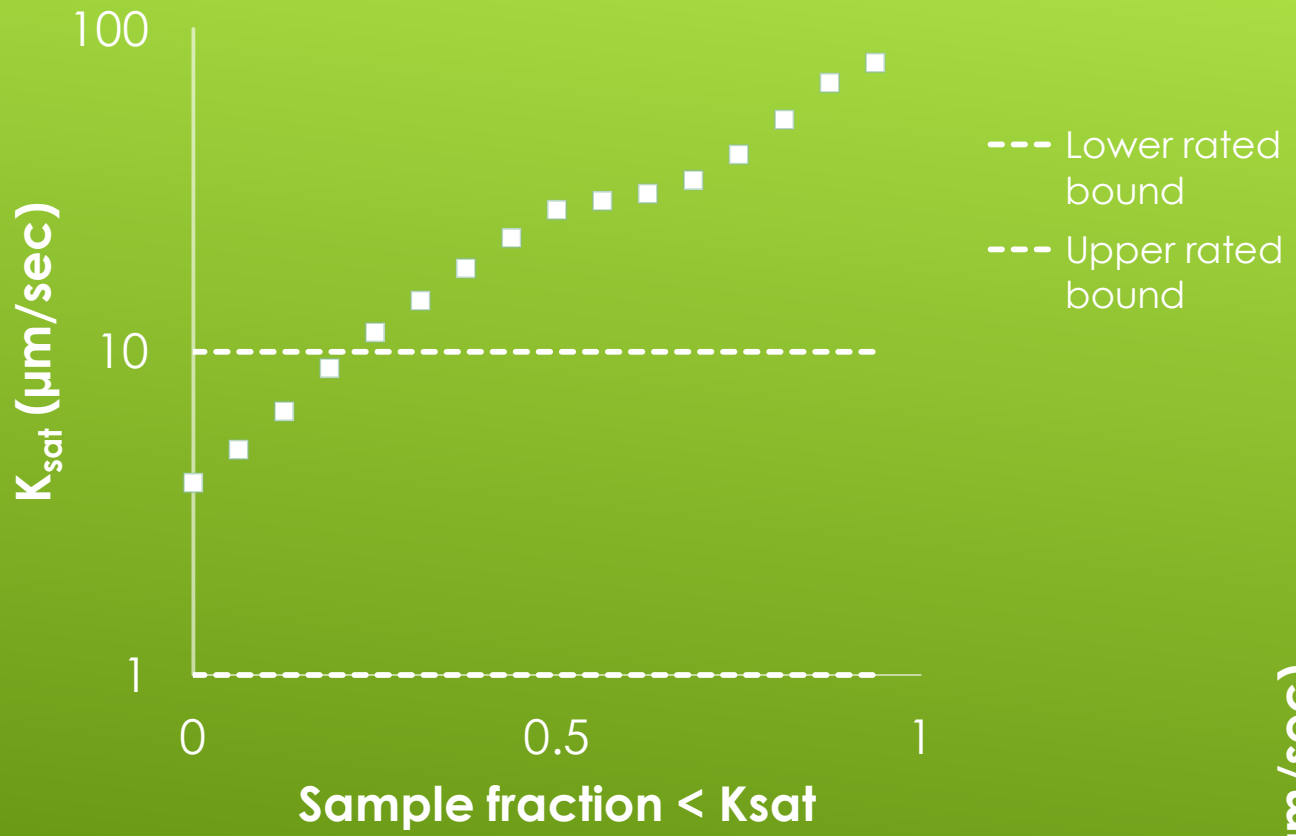

Nipe Ap
1000
100
10
1
K_{sat} (µm/sec)
0
0.5
1
Sample fraction < K_{sat}
Lower rated bound
Upper rated bound


Nipe Bo
100
10
1
K_{sat} (µm/sec)
0
0.5
1
Sample fraction < K_{sat}
Lower rated bound
Upper rated bound

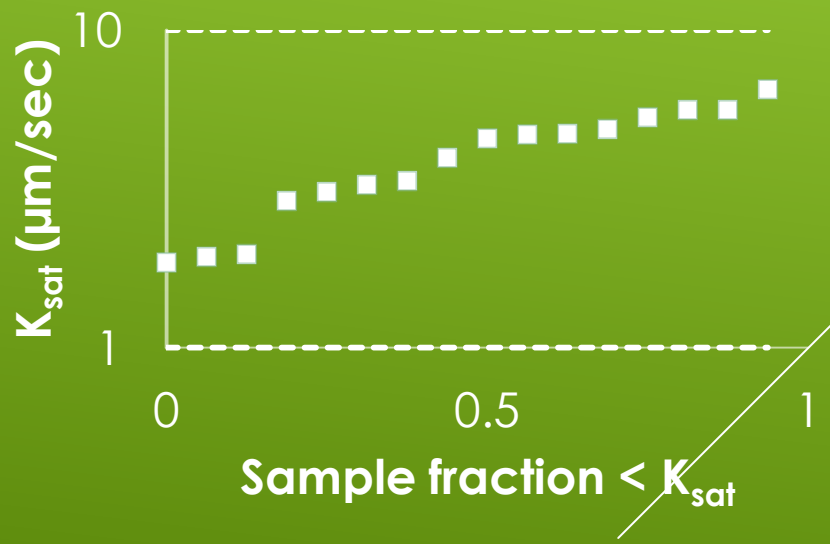

Coto Bo
Lower rated bound
Upper rated bound
1000
100
10
1
0.1
K_{sat} (µm/sec)
0
0.5
1
Sample fraction < K_{sat}


Pandura Bw
Lower rated bound
Upper rated bound
100
10
1
K_{sat} (µm/sec)
0
0.5
1
Sample fraction < K_{sat}

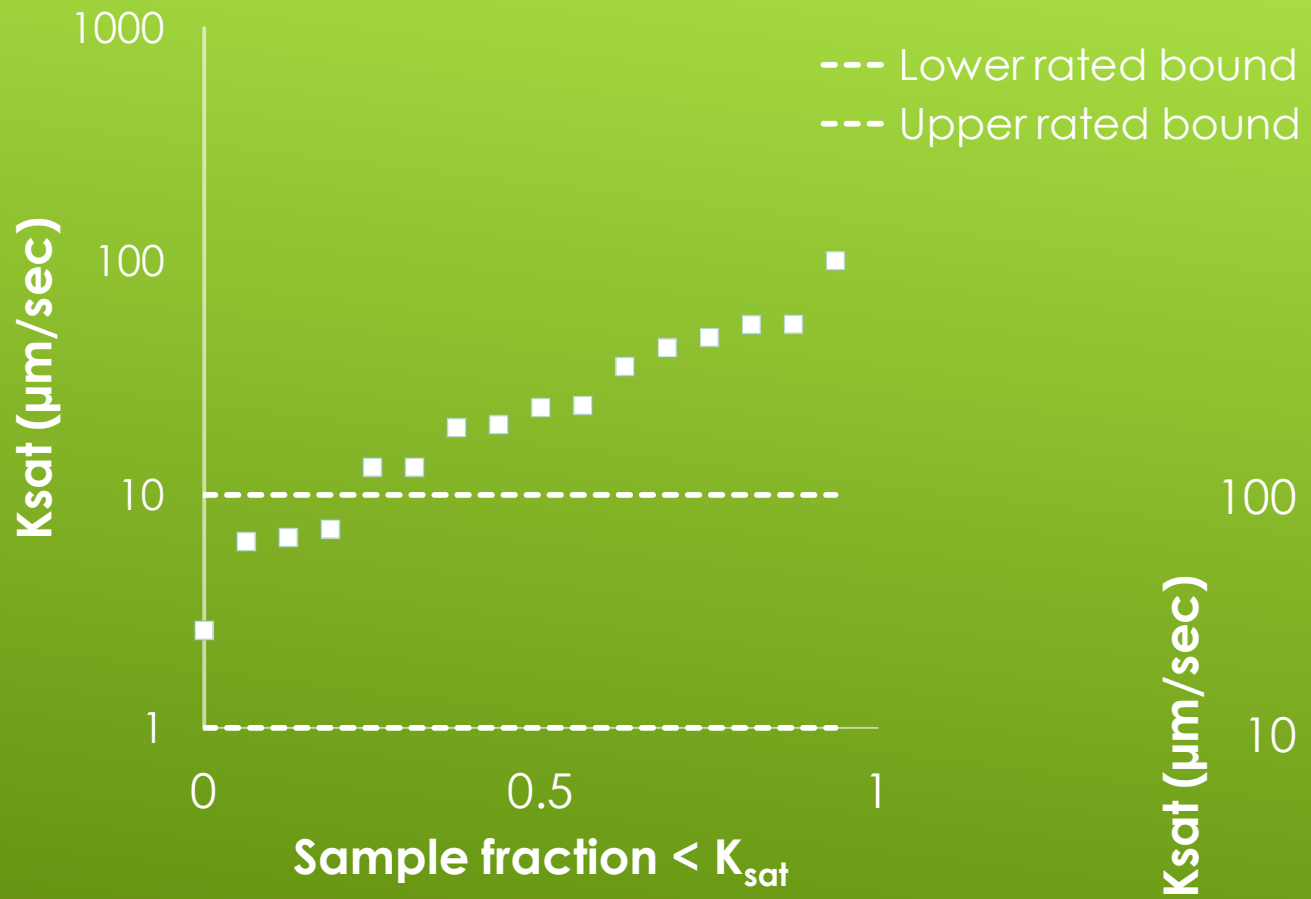
Aceitunas Ap



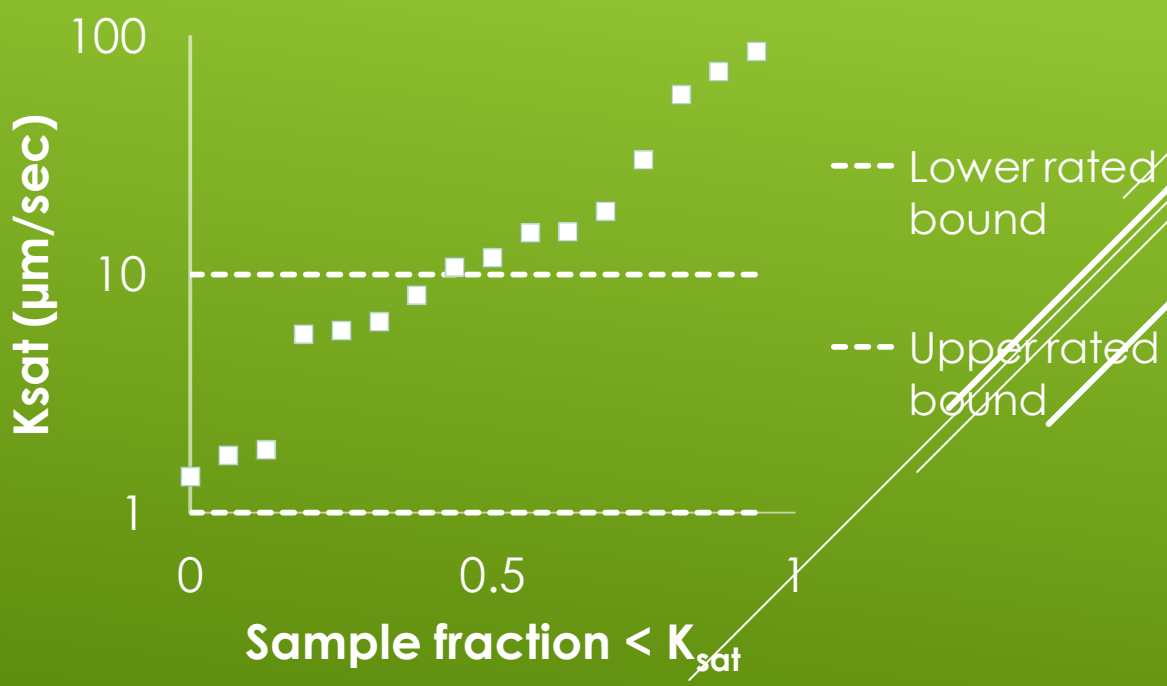
Aceituna Bt



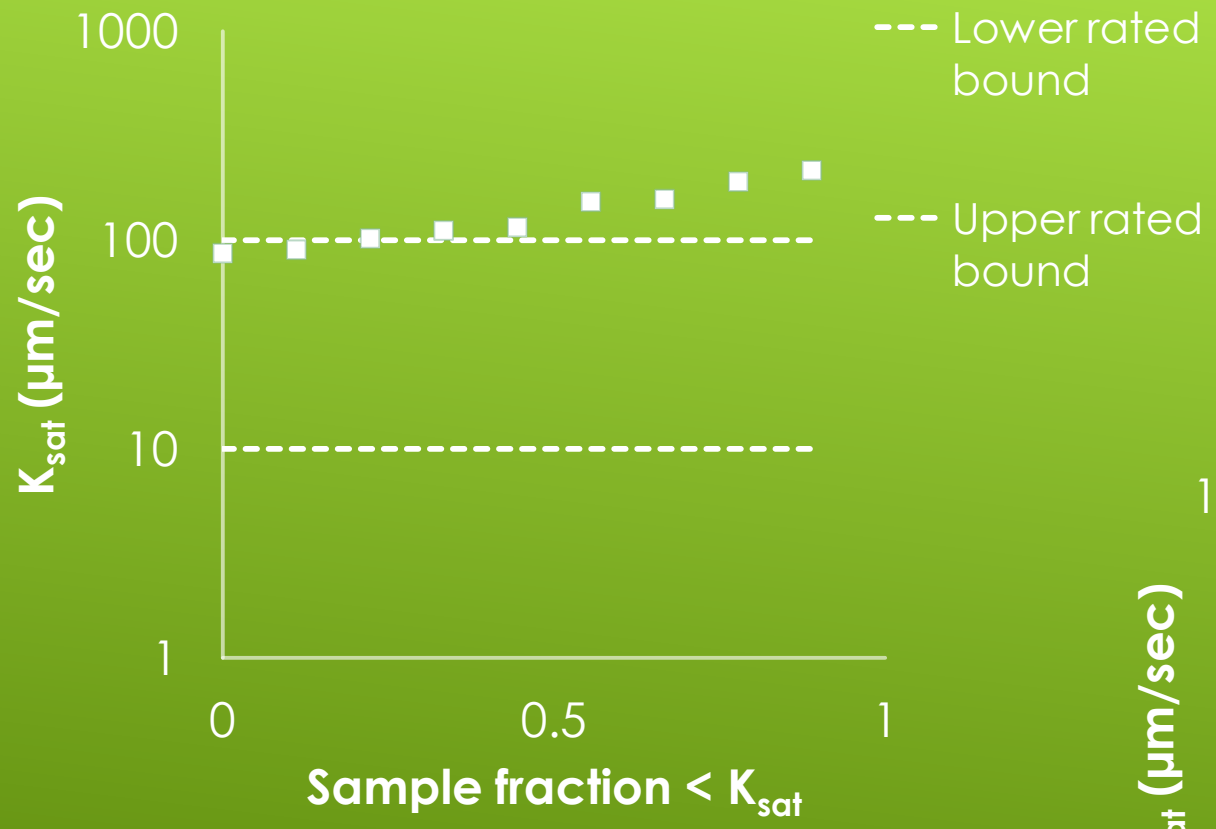
Humatas Ap



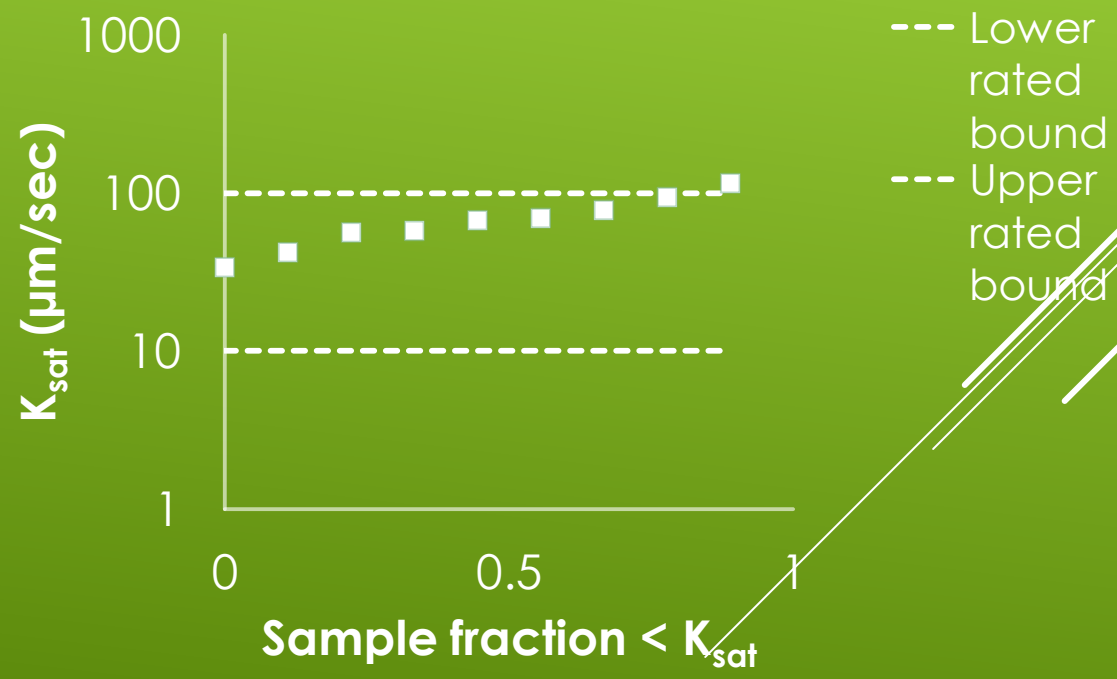
Humatas Bt



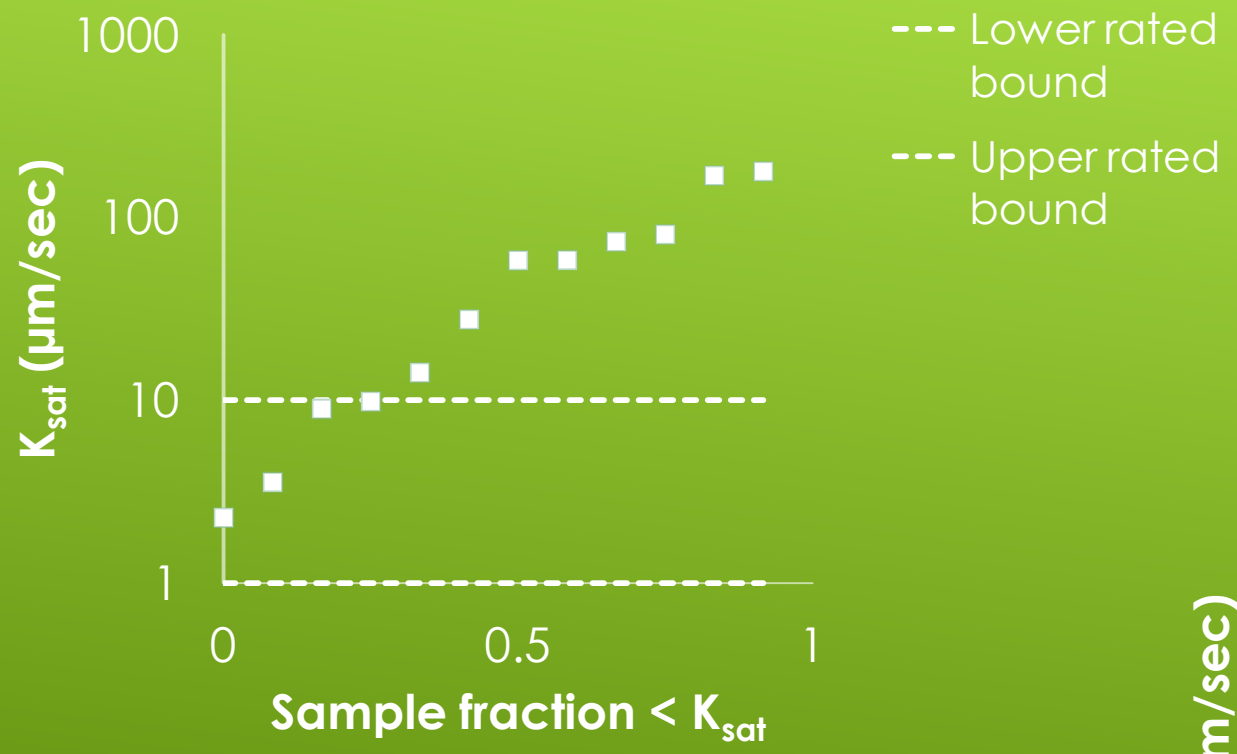
Bahia Ap



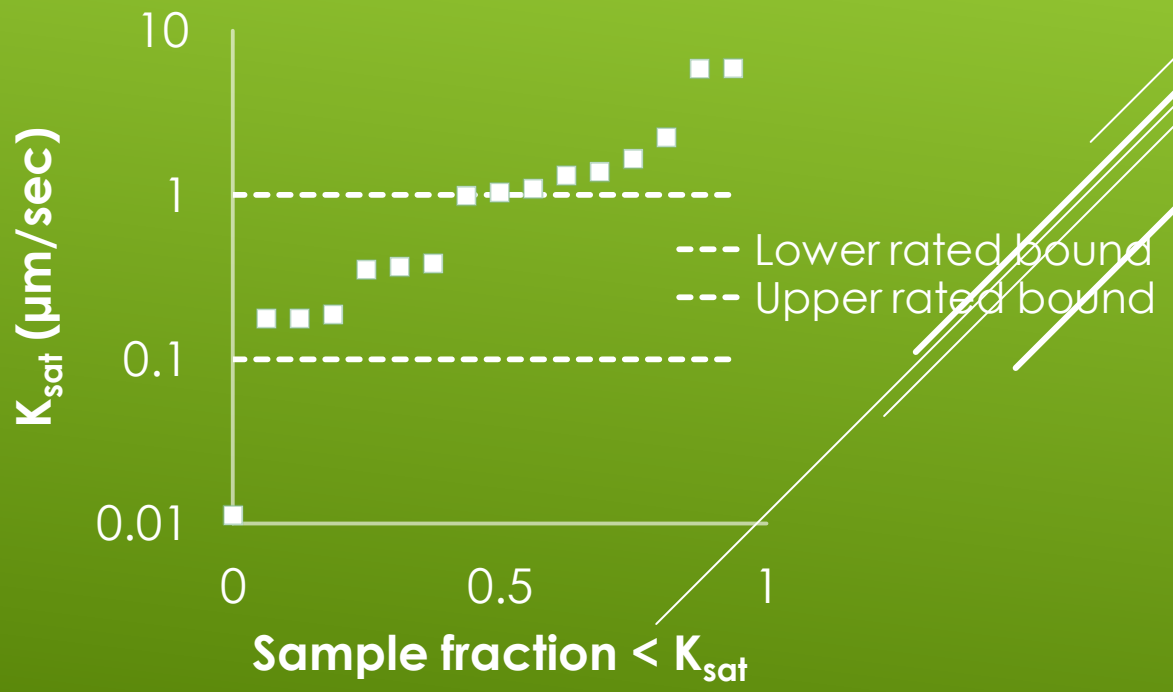
Bahia Bt

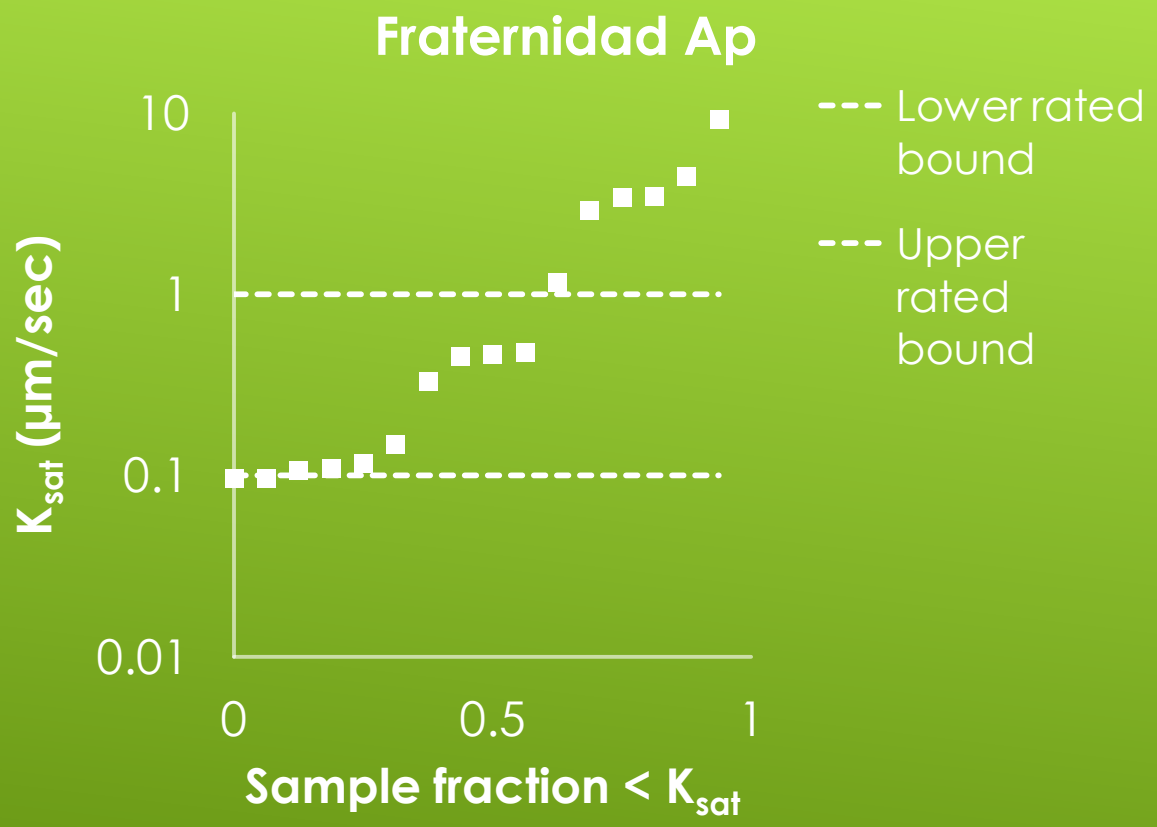


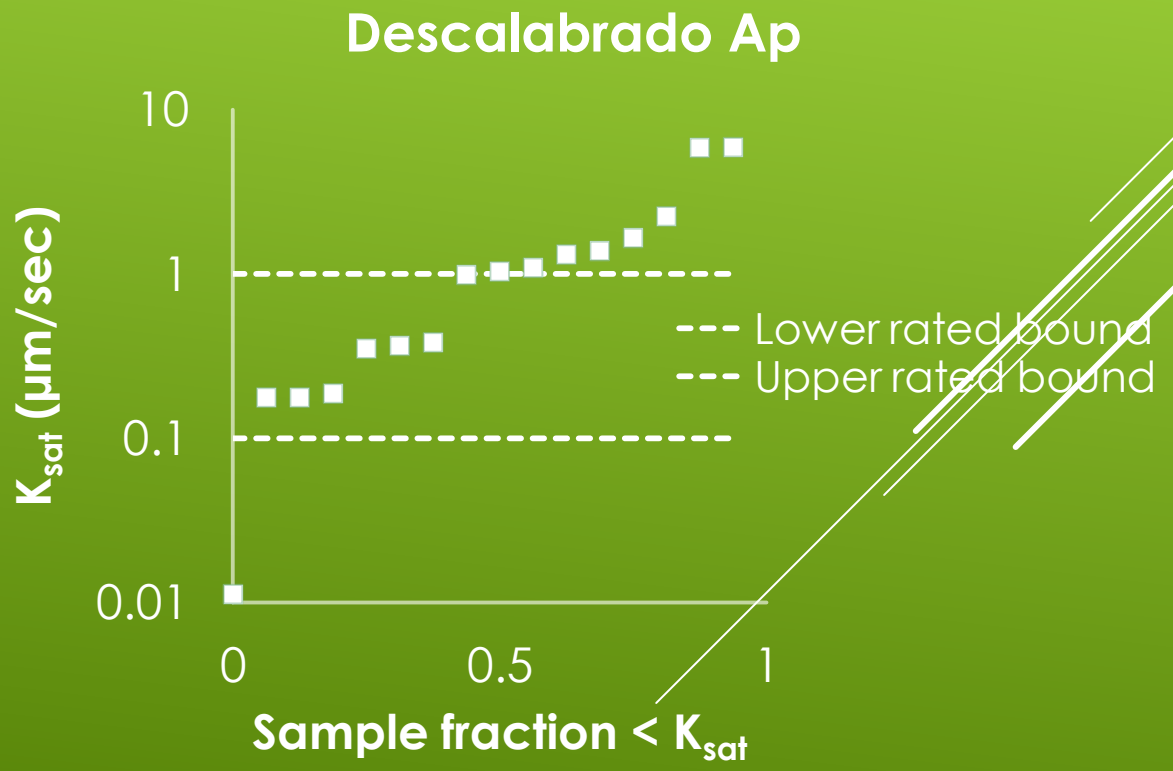
Toa Ap



Descalabrado Ap




Fraternidad Ap
10
1
0.1
0.01
0
0.5
1
K_{sat} (µm/sec)
Sample fraction < K_{sat}
Lower rated bound
Upper rated bound

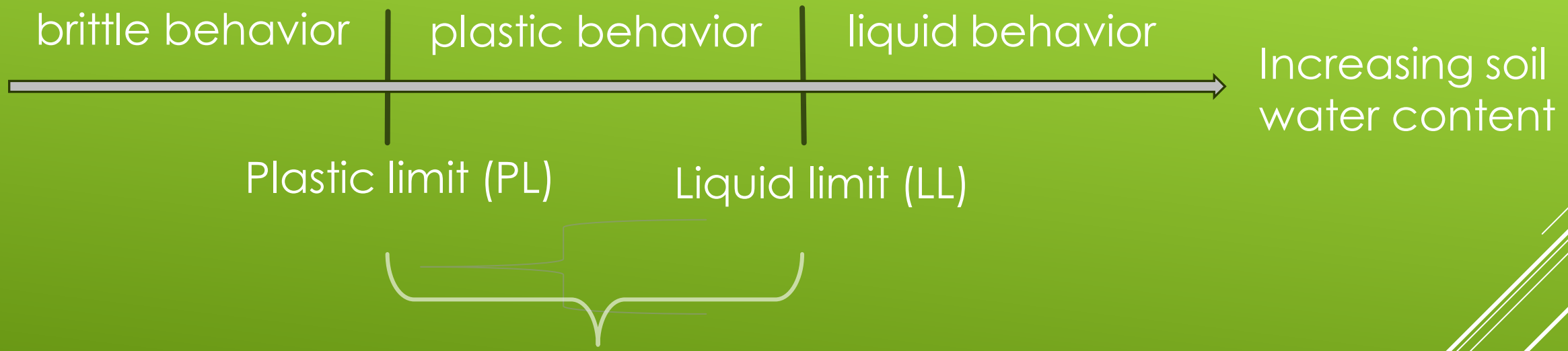

Descalabrado Ap
10
1
0.1
0.01
0
0.5
1
K_{sat} (µm/sec)
Sample fraction < K_{sat}
Lower rated bound
Upper rated bound

Soil series	Expected	Higher K_{sat} by		Lower K_{sat} by	
	K_{sat} category	one category	two categories	one category	two categories
Aceituna A_p	0.25	0.75	-	-	-
Aceituna B_t	1.00	-	-	-	-
Bahía A_p	0.22	0.78	-	-	-
Bahía B_t	0.89	0.11	-	-	-
Bayamón B_o	0.25	0.75	-	-	-
Coto B_o	0.82	0.06	0.06	0.06	-
Descalabrado A_p	0.50	0.50	-	-	-
Fraternidad A_p	0.50	0.38	0.13	-	-
HumatasA_p	0.25	0.69	-	0.06	-
HumatasB_t	0.44	0.56	-	-	-
Nipe A_p	0.38	0.56	-	0.06	-
Nipe B_o	0.38	0.62	-	-	-
Pandura B_w	0.08	0.92	-	-	-
Toa A_p	-	0.33	-	0.50	0.17

CONCLUSIONS OF K_{SAT} VALIDATION STUDY

- Measured K_{sat} values ranged over 2 orders of magnitude raher than 1 order as in the current rating system.
- Approximately half the measured values resided within the estimated K_{sat} class, with the other half of the measurements residing in the next higher K_{sat} class. (Estimates are conservative).
- This provides a safety factor for design of practices where runoff potential needs to be minimized (irrigation, land application of liquid waste). However, for expensive practices such as tile drainage, it may result in over-design and cost overrun.

ATTERBERG LIMITS



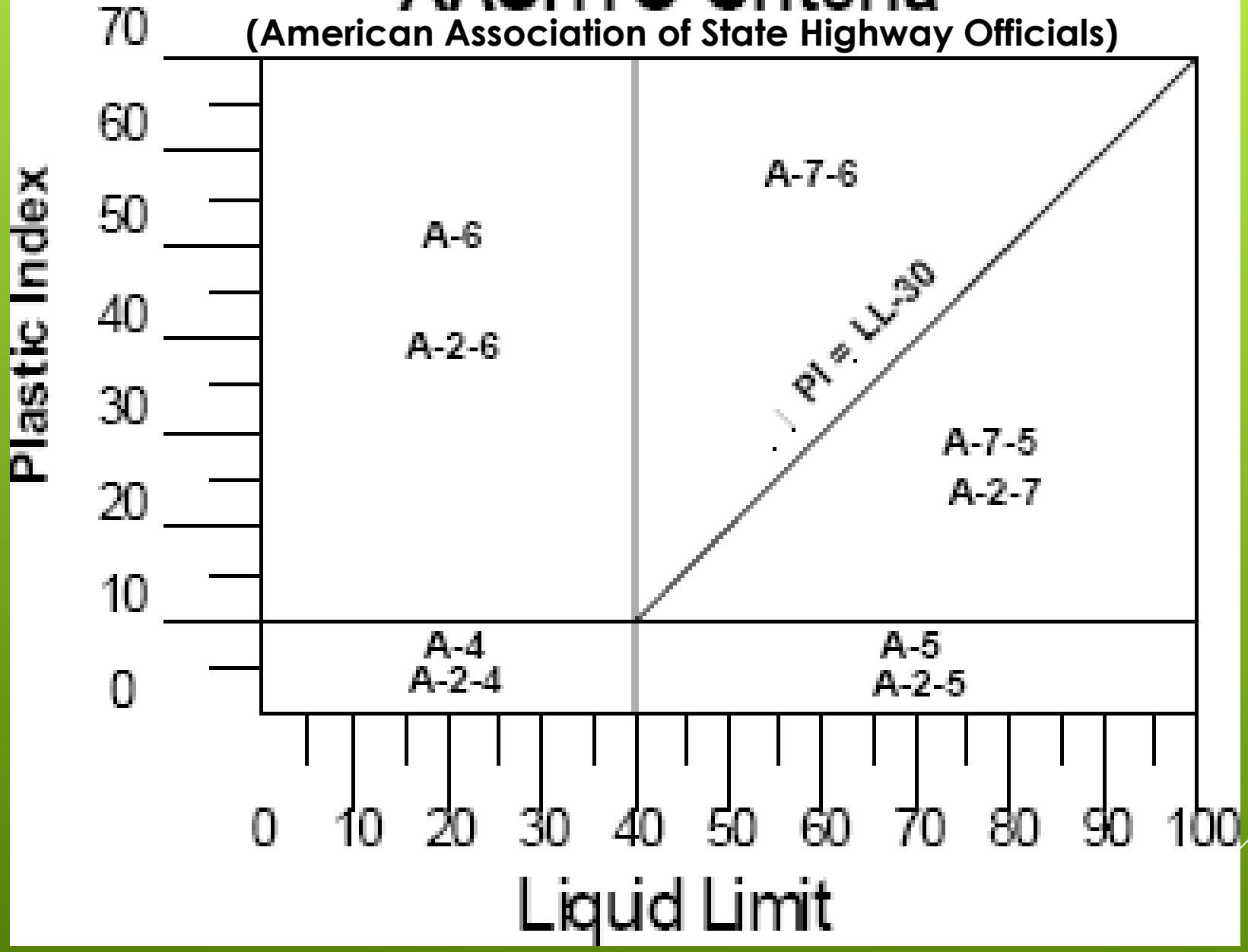
$$\text{Activity } (a) = \frac{\text{PI}}{\%\ \text{clay}}$$

USEFULNESS OF ATTERBERG LIMITS

- **Preliminary information on engineering properties of soils for design of earth structures and foundations.**

AASHTO Criteria

(American Association of State Highway Officials)



Default estimates of **PL** and **PI** in soil surveys (NSSH 818.66)

PROJECT OBJECTIVES

- Measure values of PL and PI at three locations for 8 major soil series of Puerto Rico and US Virgin Islands, and compare measurements to estimated values listed in Soil Survey reports.

- Using these data and published values of PL and PI in NCSS data bases, attempt to improve regression equations for estimating default values.